OBSERVATIONS ON THE NESTING BEHAVIOR OF ASTATA OCCIDENTALIS CRESSON IN CENTRAL CALIFORNIA

(Hymenoptera: Sphecidae)

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Recently Howard E. Evans (1957) has published biological observations on several species of the genus *Astata* together with a comparison of the behavioral patterns of the group. Subsequently we have had the opportunity of observing a relatively large colony of *A. occidentalis* Cresson in Alameda County, California. Since Evans' work included a rather thorough report on a colony of this same species at Versailles, Indiana, a comparison of the nesting habits of the populations from the two areas and some remarks on variation is of value. Evans' paper gives additional data on the nesting habits of the genus and a review of the literature.

The active colony of *A. occidentalis* Cresson was first descovered September 17, 1958, near the southern end of San Francisco Bay about two miles southwest of Warm Springs, Alameda County. Observations were made on September 20 and during the afternoons of September 23 and October 1, 1958. Weather conditions were generally clear and warm, although September 23 was somewhat windy and cooler. The nesting site was located along the bank of a slough in the mud-flat region marginal to the bay where the soil generally is a dense, moist alkaline clay with a high organic content. Vegetation in the area consists mostly of low-growing plants, primarily pickleweed (*Salicornia ambigua* Michx.), and fat-hen (*Atriplex hastata* L.). Interspersed throughout the habitat are areas of bare soil which are utilized extensively for nesting by other aculeate Hymenoptera (*Anoplius, Ageniella, Motes, Sphex, Chlorion, Nomadopsis,* etc.). The *Astata* burrows were located in an area about twelve by three meters and contained an estimated forty active female wasps. However, the twenty-nine burrows under observation were concentrated in a small portion of the site in a zone about one by three meters. In this particular area the soil consists of a 2–3 cm. layer of loose loam at the surface, and a relatively uniform understory of moist clay and is in part covered by boards, other debris and sparse growths of *Salicornia.* Most of the wasps had selected spots for burrow construction on flat ground, just above the crest of the slough bank, however, some burrow entrances were in evidence on higher areas of the south-

facing slope and entered the ground nearly horizontally. The burrows were found in the open, near, or under the pickleweed and seemed to be randomly located with respect to the plant cover and micro-topography of the site. The Warm Springs population often had burrow entrances within a few centimeters of each other. In contrast, Evans found the Indiana population in the hardpacked clay of a baseball diamond which was completely devoid of vegetation, and, perhaps due to the nature of the site, the burrows there were located no closer to one another than half a meter.

At Warm Springs, males were observed in numbers in and around the nesting site. During the warmer part of the day individuals were commonly perched on terminals of the *Salicornia* or on other protruding objects from which they occasionally darted out in short flights over the nesting area, usually returning to the same perch in a few seconds. Although Evans did not observe males of *A. occidentalis,* possibly due to the late stage of the nesting season, he reported similar flights by the males of *A. unicolor* Say, but in the latter species the perches were located some distance from the burrows. It is presumed that these flights are associated with the mating behavior, but copulation has not been observed in either species. On the basis of his observations of *A. unicolor,* Evans concluded that the females must fly into the area occupied by the males for mating. However at the *A. occidentalis* site the males were in close proximity to the females engaged in nesting. As was reported for *A. unicolor,* these flights occurred without any apparent stimulus, and active females in the area were never approached by the males during the course of our observations. It seems likely that females copulate only once, shortly after they first emerge.

The only digging activity observed was that being carried out by females with established burrows, and probably this was associated with cell construction. The process of removal and dispersal of soil was similar to that reported by Evans. In the Warm Springs colony the burrows were in general shorter and had fewer cells than in the Indiana population. In our excavations we found the burrows ranging in length from 11.0 cm. to 14.5 cm. and terminating about 9–10 cm. below the surface, whereas Evans reported that the burrows may be as much as 18 cm. long and 12 cm. deep. He also stated that a completed burrow may have up to 14 provi-

sioned cells, but our excavations showed only three to six cells associated with any one burrow, which presumably indicates that the provisioning was in an early stage.

The prey of *A. occidentalis* Cress. consists almost entirely of adult Pentatomidae (Hemiptera), and they are stored at the bottom of the tunnel before the preparation of each cell. Cell construction apparently is not initiated by the female wasp until enough bugs are accumulated to fully provision it. The elliptical cells are smooth-walled and vary somewhat in size, averaging about 7 by 16 mm. (8 by 15 mm. in Evans' study). They are constructed singly or often in linear series up to four cells in length as short side burrows to the open tunnel. When the cells were in series, we found them to be separated by filled portions 6–11 mm. thick as compared to thin portions (1–3 mm. thick) in the Indiana study on the species. In addition, we found a slightly greater range in depth of the location of the cells (6–15 cm. as opposed to 6–12 cm. reported by Evans).

The provisioning behavior of the females in the Alameda County population was essentially similar to that observed in the previous study on the species. During the course of our observations the females did not carry out as pronounced a pattern of circling around the burrow entrance on leaving as that described by Evans. This pattern, presumably one of area recognition, was quite irregular and ranged from direct departure to running up nearby vegetation or circling a small area once or twice. It seems possible that the vegetation in the Warm Springs site was of some significance in reducing the area recognition patterns in that it supplied nearby landmarks. Provisioning at the Warm Springs site was carried out slowly. The earliest that females were seen with prey was about 11:00 a.m. (Pacific Daylight Time). In the three hour period from 11:00 a.m. to 2:00 p.m., three bugs was the maximum number to have been brought in by any one female. Most of the active females had stored only two stinkbugs during this time. The stortest interval between two successful provisioning flights by a female was 13 minutes, but the average time required for a hunting trip was a little over an hour. Our limited data did not indicate any correlation between the previous experience in provisioning and the time length of trips as has been shown for other Sphecidae (e.g. *Cerceris;* Linsley & MacSwain, 1956).

The prey taken from cells and female wasps consisted of 255 adult and two nymphal pentatomids representing six species in the following numbers:

Adults:

Holcostethus limbolarius (Stål)	164
Thyanta brevis Van Duzee	77
Thyanta pallidovirens pallidovirens Stål	7
Perillus bioculatus (Fabricius)	4
Thyanta punctiventris Van Duzee	3

Nymphs:

Trichopepla ?aurora Van Duzee	1
Thyanta pallidovirens pallidovirens Stål	1

All the previous prey records for *A. occidentalis* have been adult Pentatomidae, and this use of adults has been employed as a biological criterion for the species since other species of *Astata* prey on immature Hemiptera. The finding of the two nymphs indicates that this criterion is not an exclusive characteristic, and possibly it may depend in part upon the availability of prey. The two nymphs were found in cells of separate burrows which in each case had many adult bugs stored. The stage of wasp larvae in other cells indicated that the two cells containing the nymphs were relatively recently provisioned.

As found in the Indiana population, individual wasps usually preyed on only one or a very few species of stinkbugs. One female had collected 24 pentatomids, all individuals of *Thyanta brevis,* a second had stored 24 *Holcostethus limbolarius* and 22 *T. brevis.* However, one cell was unearthed which contained four different prey species (one *P. limbolarius,* three *T. brevis,* one *T. punctiventris,* one *T. p. pallidovirens*). The source of the prey is unknown. It has been assumed in many solitary wasp studies that the female repeatedly returns to the same habitat where prey is available, and this might account for the relative uniformity in bug species selected by *A. occidentalis* females.

Fully provisioned cells were found to contain from four to nine bugs, averaging 6.3, a significantly higher number than that reported for the species in Indiana. It is possible that the average of 3.8 bugs per cell in the latter population is at least in part due to a larger average size of the pentatomids since the predominant species of prey at Warm Springs have smaller individuals than those recovered by Evans. The prey was usually placed in the cells

in the head-in, venter-down position reported by Evans for both *A. occidentalis* and *A. unicolor*, but a certain amount of variation was observed. This was especially noted in the final few bugs of a cell, and possibly it was due to the smaller size of the prey in the Alameda County colony causing them to not fit uniformly in the oval cells. The placement of the egg is also identical with that recorded for *A. occidentalis* and *A. unicolor*.

The transport of prey is much the same as observed in the Indiana population. Some variation was noted in the manner in which the wasp supported the prey while walking near the burrow. The smaller bugs were grasped in the wasp's mandibles by the base of the beak, while in transport of larger prey she provided additional support with the fore and mid legs, although these were used for walking at the same time. On arriving at the site with prey, the female alighted on the ground or on the *Salicornia*, usually about 10–20 cm. from the burrow, and as Evans reported for the species, the approach to the burrow entrance which followed was usually quite circuitous.

None of the bugs in our study recovered from the effects of the sting. A great deal of variation in these effects was nonetheless noted. Some in freshly provisioned cells had already died, while others were kept alive in the laboratory and responded to touch for many days. One individual showed reaction for 39 days.

In contrast to the colony studied by Evans which was heavily parasitized by miltogrammine flies, only a small percentage of the cells exposed by our excavations had been destroyed by natural enemies. Although adult specimens of three species of miltogrammine sarcophagids (*Senotainia litoralis* Allen, *Metopia leucocephala* Rossi, *Metopia* sp. near *inermis* Allen) were collected in the nesting site, none were seen to follow prey-laden females, nor were maggots of these flies encountered in any cells. Of over 50 cells seen, two had been parasitized by a larger fly, one had been destroyed by ants and onther by mold. Neither of the adult flies emerged from the puparia. Two hymenopterous parasites were collected in the nesting area, but no definite association could be shown for these. Several females of the tiphiid wasp, *Myrmosa bradleyi* Roberts were taken crawling about the nesting site, and one male was netted nearby. One individual was seen to enter an *Astata* burrow, and in another instance a female *Myrmosa* was recovered during the excavation of a nest tunnel. Three specimens

of a chrysidid wasp, *Hedychrum* sp. were collected flying about the burrow sites. In addition, remains of sphecid wasps of several genera were found in the webs of Black Widow Spiders, *Latrodectus mactans* (Fabr.) amongst the *Salicornia* in the nesting site, and this spider is assumed to be an occasional predator of *A. occidentalis* in this locality. Finally, remains of excess stored pentamoids were found in several instances to be utilized by an undetermined dipterous scavenger.

Acknowledgement for determinations is gratefully made to Dr. R. M. Bohart, University of California, Davis (the *Astata* and *Hedychrum*), Professor H. J. Reinhard, Texas A & M College (Sarcophagidae), Dr. Herbert Ruckes, American Museum of Natural History, New York (Pentatomidae), Marius S. Wasbauer, University of California, Berkeley (the *Myrmosa*), and to Dr. J. W. MacSwain, University of California, Berkeley, for reading the manuscript and offering helpful suggestions.

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